Establishing Simulation Credibility for Navy Operational Test and Evaluation

Lessons from the
Rolling Airframe Missile (RAM) Program

NAVMSMO VV&A Technical Working Group

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BRIEFING OBJECTIVE

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Credible Models for Credible Answers . . .

- **Give overview of lessons learned from the Rolling Airframe Missile (RAM) Program on establishing credibility of simulations to support Navy OT&E**

  - **Program background**

  - **Process successfully used to generate accreditation case for the RAM Block 1 6 Degree-of- Freedom (DOF) Simulation**

  - **RAM's keys to success in integrating V&V into simulation development**

Take Aways

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Credible Models for Credible Answers . . .

● **Handouts with practical tips**

   ● **Effective communication between M&S developers and operational testers (Kilikauskas and Emmert 98)**

   ● **Increasing the value of informal simulation development records with minimal effort**

   ● **Forming an effective team of M&S customer, developer and accreditation support agent**

● **Check our website for more information:**

   ● **www.nawcwpns.navy.mil/~jasa**

PROGRAM HISTORY

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- **Rolling Airframe Missile (RAM) is a ship-defense missile system being developed jointly by the US and Germany**

- **Program began in mid 70's**

- **Block 0 introduced into the Fleet in 1991**

- **Block 1 upgrade focused on infrared**

  - **Improved IR sensitivity**

  - **IR only guidance mode**

- **Block 1 passed OPEVAL in 1999**

- **FOT&E scheduled for 2002**

KEY RAM
OPERATIONAL PRINCIPLES

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TARGET RF

PASSIVE RF
OR AUTONOMOUS
IR MIDCOURSE GUIDANCE

IR TERMINAL GUIDANCE

IR
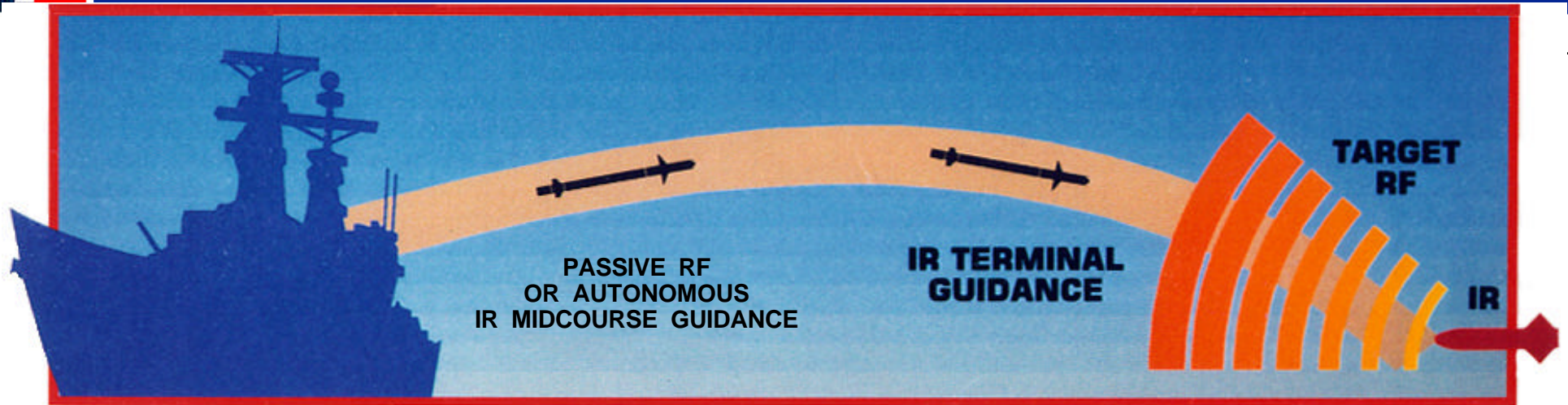
Supporting Systems

RAM Guided Missile Weapon System

Electronic Support Measures

- Passive
- Bearing, RF Power/ Frequency

Radar

- Active
- Bearing, Range, Velocity

External Designation Source

- Association (ESM/Radar Data)
- Threat Evaluation
- Weapon Assignment
- RAM Designation

Launcher System

- Mode Selection
- Initialize and Fire Missiles

Missile

- Acquire Target, Guide in RF and Point IR Gyro
- Transition to IR Homing
- Target Detection Device
- Warhead Activation

Participants and their Simulations

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- **Naval Air Warfare Center Weapons Division, China Lake**

  - **6DOF Simulations of Block 0 and Block 1**

  - **Detailed Seeker Simulation**

  - **Combined Simulation under development**

  - **Hardware in the Loop Simulation for Block 0 and Block 1**

- **Raytheon Missile Systems (US Co-Developer)**

  - **6DOF Simulations of Block 0 and Block 1**

  - **Computer in the Loop (CIL) Simulation**

- **Bodenseewerk Gerätetechnik GmbH (German Co-Developer)**

  - **All Math Model Block 0 and Block 1**

  - **Computer in the Loop (CIL) Simulation**

  - **Hardware in the Loop Simulation Block 0**

M&S Uses within RAM Program

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- **M&S used extensively throughout Block 0 and Block 1**
  - **Design Evaluation**
  - **Performance Studies**
  - **Pre/ Post Flight analysis**
- **Block 0 6DOF accredited for use in OPEVAL of Block 0 system based upon an independent assessment**
- **Block 1 6DOF and Combined Sim slated for use in FOT&E of Block 1**
  - **6DOF accreditation pending**
  - **Combined Simulation to undergo assessment Fall/Winter 2000,**
  - **Endgame tools to undergo assessment Fall/Winter 00**

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Credible Models for Credible Answers . . .

Steps to Accreditation
A Practical Approach

Definition

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Credible Models for Credible Answers . . .

- **Accreditation is a <u>decision</u> that a model or simulation is adequate for a <u>specific purpose</u>**

- **Decision generally based upon an assessment, sometimes called an accreditation case**

    - **Does the M&S have the required characteristics?**

    - **Is there adequate evidence of credibility?**

    - **Is there adequate supporting documentation**

- **The accreditation agent's primary goal is working in cooperation with the accreditor (COTF), the sponsor (generally the acquisition program office), and M&S developers to develop a meaningful case**

VV&A Process

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| Analyze Application |

| Develop M&S Requirements, Acceptance Criteria and Info Requirements |

| Research Model Characteristics |

Focus on M&S Use in FOT&E

| Evaluate M&S against Requirements |

Focus on Accreditation

| Present Accreditation Case |

| Make Accreditation Decision |
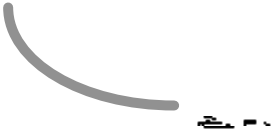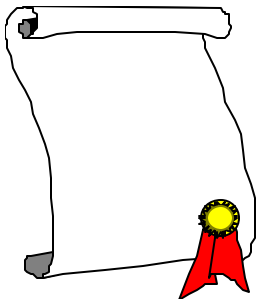
Analyze Application

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- **Help operational testers to think through how they intend to use M&S to supplement OT&E for this particular program**

  - **What analysis questions (COIs) are they trying to answer? What MOEs are they using to quantify answers?**

    - **Define terms even if you think they are obvious**

  - **What weaknesses or limitations of their live test program are they trying to mitigate?**

  - **Do they really need M&S at all?**

- **Get them to write it down and sign their names to an intended use statement**

- **Intended use statement forms the foundation of a meaningful and thorough accreditation case**

- **"Effective Communication" paper has lessons based on hard experience (Emmert and Kilikauskas 98)**

Develop M&S Requirements and Acceptance Criteria

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- **Work with M&S staff at COTF, experienced analysts within acquisition community, and M&S developers to develop a list of M&S requirements**

  - **What functions, level of fidelity, and operating features would an M&S need to adequately address the questions of interest?**

  - **COTF has the final word since they are the decision authority**

  - **Experienced analysts and M&S developers are an invaluable source of ideas for a strawman M&S requirements list**

- **Get COTF to write requirements down and sign it**

- **Work with analysts and M&S developers to decide, for each requirement, the acceptance criteria**

  - **What is the pass/fail criterion for each requirement?**

  - **Acceptance criteria should be documented in an accreditation support plan**

Develop Accreditation Information Requirements

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Credible Models for Credible Answers . . .

- **The accreditation authority has the right and responsibility to decide what information they require to support an accreditation decision**

- **Ask the accreditor what information they require**

  - **Function of policy, importance of decision, perceived risk, comfort level with M&S, level of trust between COTF representatives and acquisition community**

- **Get them to write it down as part of the M&S requirements list and sign it**

- **The intended use statement and M&S requirements list form the foundation of the accreditation effort**

Research Model Characteristics (1)

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- **Help testers and acquisition community think through which tool(s) available come the closest to meeting COTF's requirements**

  - **Work with M&S developers and program analysts to do a preliminary stoplight chart for each of the contenders against the M&S requirements list**

    - **Look for capability and limitations to choose best candidates from performance perspective**

  - **For the promising contenders, compare available documentation against the information requirements list**

    - **Helps to scope effort to prepare accreditation case and gather supporting evidence**

- **Negotiate with program office (they're the money) and COTF on which tools to pursue in earnest**

Research Model Characteristics (2)

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- **Think through each requirement on the requirements list and on the information list (parsing list into individual numbered requirements is helpful)**

    - **What would I do to determine to my own satisfaction that the M&S does or does not meet this requirement?**

    - **How much of that have we already done within the community? How much is documented and available?**

    - **What resources would I need to do each of these things that hasn't already been done?**

    - **Do I have or can I get those resources?**

    - **What evidence would I need to convince someone else? Do I have the resources to generate that evidence?**

- **With all this in mind, think through what you can really do for each requirement with what you have to work with**

Research Model Characteristics (3)

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- **Develop draft accreditation support plan outlining what you can really do, the weaknesses of the plan, and what risk you believe the decision maker incurs if an accreditation assessment is based on this information**

  - **You never have as much data as you'd like**

- **Run it by COTF, plead your case, get their feedback**

- **If they're basically agreeable, you're on your way**

- **If COTF wants more than you can do, bump it upstairs**

  - **It becomes a negotiation between COMOPTEVFOR management and the program office**

- **In the meantime, get started implementing your plan because if you wait until everybody agrees to everything, you'll never make it**

Research Model Characteristics (4)

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- **The accreditation support plan is the backbone of your accreditation support effort**

  - **Documents what information you will provide to COTF to help them to come to an accreditation decision for specific tools for a specific purpose in OT&E**

Evaluate M&S Against Requirements (1)

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- **The RAM community held a special session of the Simulation Working Group to examine the evidence gathered and to determine among ourselves if we believed the case was complete and compelling**

- **SWG review planned carefully, run in a very structured manner, and carefully documented afterwards**

  - **Simulation experts from prime contractor and government**

  - **Witnesses from program office and COTF**

- **Basic question: would a prudent person find this case adequate?**

Evaluate Against Requirements (2)

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- **Worksheets listing both M&S requirements and information requirements and summarizing evidence presented against each requirement were helpful to reviewers**

- **Nobody left the room without signing their assessment**

- **Based on evidence presented, review group came to consensus on uses for which simulation was credible, limitations to credible use, and recommendation for certification by RAMPO and accreditation by COTF**

- **Almost all evidence presented at review was put on a CD ROM, placed in document retrieval system and forwarded with recommendation to RAMPO**

  - **Information not on CDROM is available for inspection**

Present Accreditation Case

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- **Summary briefing prepared for RAMPO and briefed to program manager**

- **RAMPO signed "certification" letter per COTF instructions and requested that COTF accredit the simulation subject to the limitations noted in the certification letter**

- **Certification letter and CDROM submitted to COTF for their internal assessment**

Accreditation Decision

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- **The ball is in COTF's court to prepare a case to submit to the Commanding Officer**

  - **The accreditation case you submit should form the bulk of their argument**

  - **If COTF personnel have to do much more than summarize what you presented, you didn't do your job**

- **Commanding Office at COMOPTEVFOR makes the final decision to accredit for specific use in supplementing OT&E/FOT&E**

  - **Get the OTD to send you a copy of the signed statement**

Key Elements of RAM's Accreditation Case for Block 1 6DOF Simulation

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- **Intended Use Statement signed by COTF**

- **M&S Requirements List signed by COTF**
  - **M&S and Accreditation Information Requirements**

- **Accreditation Support Plan**
  - **Acceptability Criteria for each requirement**
  - **Evidence to be presented for each requirement**
  - **Review plan**

- **Certification Review After-Action Report**
  - **Assessment, recommendation of peer review panel**

- **Supporting Evidence**
  - **Evidence from Cert Review, other info in Accred Support Plan**

- **Certification Statement from RAMPO**

- **Accreditation Case to COMOPTEVFOR**
  - **All documents listed above on CDROM with cover letter from RAMPO**

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Integrating Credibility into Simulation Development

RAM's Keys to Success

The Secret to Our Success

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- **Working with the RAM M&S community and COMOPTEVFOR on this accreditation package was a pleasure for several key reasons**

    - **There was a wealth of material to work from**

        - **RAM M&S community was doing the right thing way before I came along**

    - **COMOPTEVFOR personnel were willing to engage, work hard and stretch themselves**

    - **JASA was persistent (I don't get mad, I just never leave)**

- **Details may vary, but every acquisition program could put these ideas to use**

Key #1: RAM M&S Team Planned Ahead

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- **First validation plan published in 1987**
  - **Simulation team was thinking about credible simulation well before VV&A and SBA were hot topics**

- **Followed philosophy developed by Robert Sargent and written about extensively in the Society for Computer Simulation magazine "Simulation"**

- **Chose model development and V&V approach well suited to the simulation development environment**
  - **Start simple and add complexity as your understanding of the real system increases (spiral approach)**
  - **Simulation evolves as real system under development evolves**
  - **Simulation model is refined as more validation data becomes available (model-test-model)**

Key #2: RAM Maintained an Effective Forum for Technical Interchange on M&S

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- **RAM Steering Committee recognized the value of simulation analysis to the future of RAM growth**

- **In 1986 established a Simulation Working Group made up of representatives from each organization**

- **Group was chartered to ensure consistent and credible simulation capability existed at each facility**

- **Recognized the individual roles, unique features and capabilities of each facility**

- **Recognized that no one facility could do all the work needed**

RAM Simulation Working Group Accomplishments

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- **Extensive comparisons and correlations conducted between simulations developed by different partners**

- **Extensive technical discussions of simulation results, problems, and possible solutions**

- **Periodic formal peer reviews with a written record**

- **Extensive pre-and post flight analysis with flight test data throughout development of both Block 0 and Block 1**
  - **Thought ahead about what data was likely to be captured or not captured during flight tests**

- **Established an audit trail of changes from one version of the simulation to another**

- **Established well-defined test cases to check changes**

Secrets to the RAM SWG's Success

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- **RAM SWG has extraordinary combination of talented technical participants and visionary management.**

- **Team members from all three major simulation developers have extensive experience in simulation development**

- **Developed a high level of mutual respect and trust**

- **Trust between members led to a high level of candor in discussing technical problems**

- **Usefulness of technical exchange became evident to management**

- **Team members focused on project success**

- **Requires effective leadership that allows members to formulate tasks and goals.**

RAM: Supportive Management

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- **SWG had amazingly low turnover of individuals even when the prime contractor was bought out twice**

- **Senior management at all three major agencies was committed to making SWG useful**

  - **No one agency had all the tools and resources to make the acquisition program successful**

  - **Management at one agency respected capabilities of other agencies**

  - **Management understood importance of simulation in the program**

- **SWG chairman took the time to put out minutes from each meeting with attendance list, action items, summary of activities, hard copy of unclassified presentations**

Key #3: RAM Community Made Use of Natural Documentation Points

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- **Simulation Parameters Document published early in Block 0 days**

- **Simulation reviews part of PDR and CDR for missile**

- **Model Management Plan, Validation Plan, and Configuration Management Plan entered into RAM documentation archive**

- **Accreditation Case and supporting evidence put on a set of CD ROMs that are entered into archive**

- **Preflight predictions from more than one simulation regular item on MRR and TRR agendas**

- **Post flight analysis results regularly briefed at SWG and other venues**

    - **Presentations form part of record**

Key #4: RAM M&S Team Made Intelligent Use of Tools

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- **NAWCWD team made extensive use of comment fields in "SourceSafe" Configuration Management package**

  - **Archive previous versions of simulation**

  - **Document changes to simulation and reason for making changes**

  - **Keep record of testing on simulation**

- **NAWCWD team used "linking" feature in PowerPoint to make executive summary level presentation of verification and validation evidence with links to presentations with technical details**

  - **All data contained on a single CDROM**

  - **Not the optimum tool yet because someone can still alter the material**

Conclusions

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- **It is possible to incorporate V&V into everyday simulation development practice**

  - **RAM has been doing it for 20 years**

  - **You need quality people and management support**

- **Building a meaningful accreditation case is a lot of hard thinking and hard work**

  - **Think hard up front**

  - **Our experience may help you get off to a good start**

- **We welcome your feedback**

Contact Information

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Credible Models for Credible Answers . . .

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Effective Teaming in Supporting Accreditation Assessment

An Example from the
Rolling Airframe Missile (RAM) Program

First Annual M&S in Navy OT&E Symposium

5, 6 October 2000

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Definition

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  - **Is there adequate evidence of credibility?**

  - **Is there adequate supporting documentation?**

- **Working in cooperation with the accreditor (COTF), the sponsor (generally the acquisition program office), and M&S developers to develop a meaningful case is the accreditation agent's primary goal**

Basic Principles for Effective Teaming

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- **Need input/perspective of all major parties**
  - **End user (accreditation authority)**
  - **Simulation Developer**
  - **Simulation Proponent (party paying for development and V&V)**
  - **Accreditation Agent (not mandatory, but good ones very helpful)**
- **Use skills/experience/corporate knowledge of each party to maximum extent possible**
- **Minimize effect of weaknesses, biases, and <u>perception of bias</u> of team members**
  - **Backups describe roles and frequent weaknesses of each party and how others can help compensate**
- **Minimize disruption to ongoing simulation development and usage**

Teaming on a RAM Block 1 6DOF Accreditation Assessment: One Effective Approach

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- **Development Team**

  - **Determined approach for simulation development and V&V**

  - **Developed and documented simulation and input sets**

  - **Performed and documented verification and validation**

  - **Briefed development history and technical V&V material at expert review**

- **End User/Accreditor**

  - **Developed intended use, M&S requirements lists, accreditation information reqts with extensive interaction with development team**

  - **Provided heading checks as accreditation package was developed**

  - **Reviewed accreditation package and made final decision**

Ram Team: One Effective Approach

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- **Accreditation Support Agent**
  - **Wrote accreditation support plan**
  - **Facilitated working sessions and communication between end user and development team**
  - **Moderated expert review of accreditation case**
  - **Wrote supporting documents for accreditation support package and expert review**

- **RAM Program Office**
  - **M&S and VV&A responsibility consistently assigned to the (same) key person**
  - **Program office representative participated in key events**
    - **Expert review of accreditation case**
  - **Program office allocated time and resources to tasks related to accreditation support**
  - **Program Manager formally certified the simulation as suitable for the end user's stated intended use**

Details

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● **Responsibilities of each party**

● **Frequent Weaknesses**

● **How Others Can Help**

End User/Accreditor

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- **Responsibilities:**
  - **Define the intended use and resulting M&S requirements**
  - **Define the information required to perform an assessment of a simulation for accreditation**
  - **Perform final accreditation assessment and make accreditation decision**

- **Frequent Weakness**
  - **Lack of technical knowledge necessary to develop meaningful and sufficient requirements for M&S**
  - **Lack of experience and "gut feel" necessary to determine what kind of correlation one should reasonably expect to see between good test data and simulation predictions for parameters of interest**
  - **VV&A is incidental to their major goals (like planning and conducting an operational test and evaluation program)**
  - **Lack of knowledge of policy and "reasonable" practice in VV&A**

End User/Accreditor

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● **How Others Can Help**

  ● **Developers with experience in using simulation for analysis can often develop a strawman set of M&S requirements based on the intended use**

  ● **Developers with experience in comparing simulation predictions with test data can offer suggestions on 1) how close the correlation must be for a given application 2) how close one can reasonably expect the correlation to be given the uncertainties of testing**

  ● **Accreditation Support Agents can provide information on VV&A policy and best practice**

  ● **Accreditation Support Agents can arrange technical interchanges between end user and developers or other subject matter experts for the purpose of developing strawman intended use statements and M&S requirements**

  ● **Accreditation Support Agents can minimize the paperwork burden by doing the formal documentation using raw material provided by user and developer.**

M&S Developer

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● Responsibilities

- ● Develop M&S in a professional, disciplined manner

- ● Provide expertise on the characteristics of their M&S

- ● Develop and maintain documentation of the M&S

- ● Maintain effective configuration management

- ● Plan, execute and document V&V required to show that the M&S meets its original requirements

- ● Support accreditation efforts by providing users with information

M&S Developer

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Credible Models for Credible Answers . . .

● **Frequent Weaknesses**

  ● **Has difficulty separating aspirations for the product from current reality**

  ● **There is the perception of bias even if the developer has a very even view**

  ● **May not understand application area of interest to user**

  ● **May be defensive about requests for objective evidence of the quality of his product**

  ● **May not have funding to do formal documentation of M&S or V&V**

M&S Developer

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- **How Others Can Help**

  - **End User**

    - Make the effort to describe his intended application in detail, more than once if necessary

    - Explicitly state what information is required from the developer

    - Make the effort to learn about the candidate simulations and understand the implications of their limitations

  - **Accreditation Support Agent**

    - Help the end user think through what information would be most useful in supporting an accreditation assessment and what the cost/benefit is for different types of information

    - Help the user be reasonable about the level of formality required in documentation of the M&S and any V&V performed

    - Work with the developer to package accreditation support package in the format/paradigm the user wants to see

    - Find gaps in accreditation support into and suggest ways to fill the gaps

Accreditation Support Agent

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Credible Models for Credible Answers . . .

● **Responsibilities vary but can include**

  ● **Work as necessary with user and developer to ensure that the accreditation support package is sufficient to support a meaningful accreditation assessment for the end user's specific application**

  ● **Facilitate communication between different communities**

  ● **Provide up-to-date information on current policy and best practice**

  ● **Provide insight into cost/benefit trade of various V&V and documentation activities**

Accreditation Support Agent

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Credible Models for Credible Answers . . .

● **Frequent Weaknesses**

  ● **Lack of detailed understanding of specific areas of modeling, analysis, engineering, science, etc. relevant to the particular model or simulation under consideration**

  ● **Lack of in-depth understanding of the simulation under consideration**

  ● **May overlook value of existing informal documentation**

  ● **May not have sufficient authority within simulation community to task individuals or establish priority of V&V related work**

  ● **May lack knowledge of policy and standard practice within the agencies represented by the M&S developer, M&S proponent, and/or end user**

Accreditation Support Agent

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Credible Models for Credible Answers . . .

- ● **How Others Can Help**

  - ● **Developer or other subject matter experts can provide technical support**

  - ● **Members of simulation community can make it a point to show the agent the records they have and describe the work they've done in the past--err on the side of mentioning things that are too trivial rather than leave out something that may be useful**

  - ● **M&S proponent must support efforts of agent**

    - ● **Include V&V tasking in budgeting, scheduling, and work load**

    - ● **Assign V&V tasking sufficient priority compared to other tasks**

  - ● **End user, developer and proponent can make an effort to inform the agent of any local agency policies or practices related to simulation development and V&V**

Contact Information

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Lessons Learned

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Credible Models for Credible Answers . . .

● **Make sure any artifacts you want from the simulation development process are in the development contract as deliverables**

  ● **Typical artifacts are documentation of the simulation itself, V&V and test plans and reports, configuration management plans and records**

  ● **If these items are not explicitly included on on the CDRL list, the best case is that it will cost you more time and money to get them. Worst case is the information is never recorded at all.**